Power-Aware Cognitive Packet Networks

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Motivation

- Mobile nodes have limited energy
- In ad hoc routing, nodes rely on other nodes to deliver their messages
- Routing algorithms unaware of energy in nodes may shorten network lifetime
- Objective: Identify paths which intelligently distribute energy consumption

Cognitive Packet Networks

- Distributed algorithms that implements self-adaptation that searches QoS on demand
- Data flows are characterized by a QoS goal (one or more metrics)
- Packets can acquire network status (experience) as they move and this information can be exploited in future decision makings
- Different data flows can collaborate by sharing information

Information Collection and Storage

- Smart packets search for routes, dumb packets transport payload, both of which accumulate experience
- Acknowledgements distribute experience
- Information is stored in nodes along paths (mailboxes and RNNs)

Header	Cognitive Map	Payload

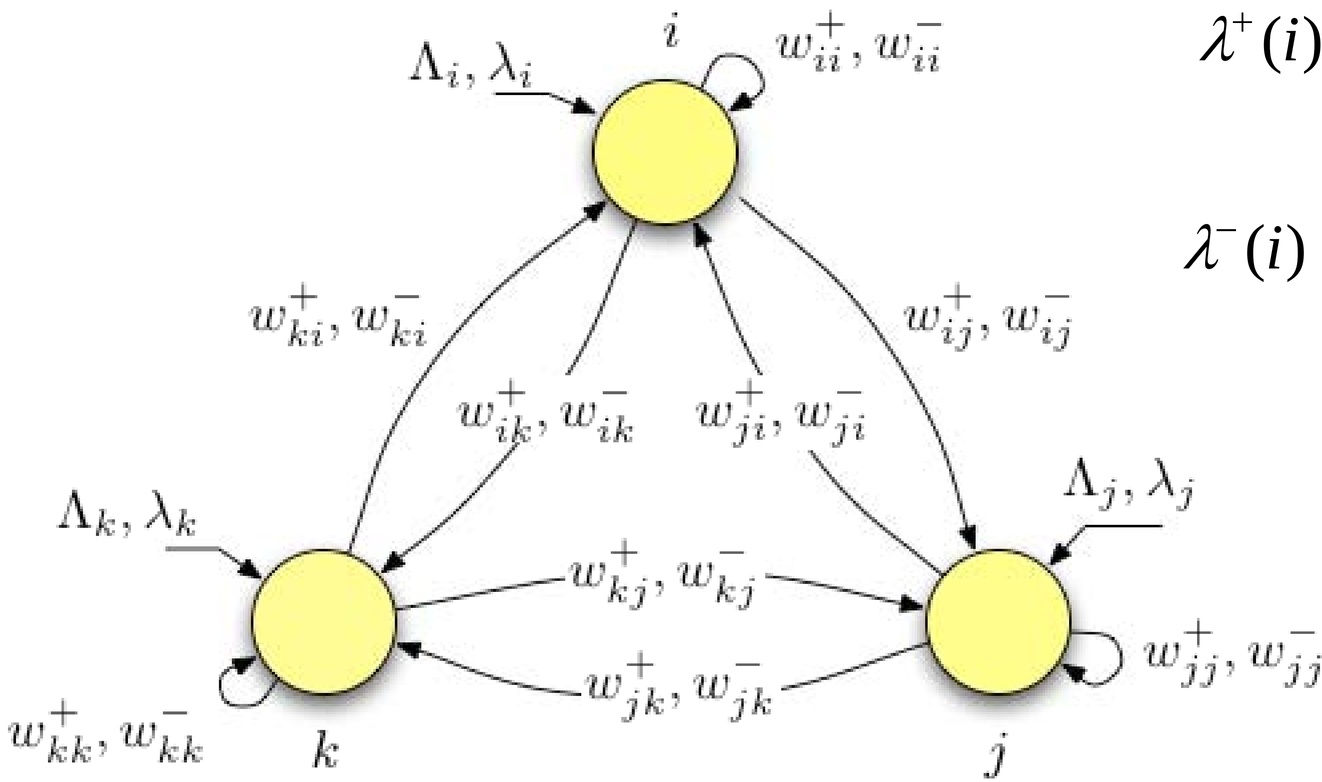
Routing Decisions

- At each hop, smart packets use a random neural network (RNN) with as many neurons as possible decisions (neighbors)
- The most excited neuron in steady-state gives the best decision for the packet

CPN in Ad Hoc Networks

- Neighboring information is acquired by listening to channel transmissions
- Each packet reception updates a time-to-live value for the sending neighbor
- Expired entries are removed
- Smart packets may use broadcasts instead of unicast decisions (RNN/RL):
  - When not sufficient information is available at a node to construct a valid RNN (for example, when the node just entered the network)
  - With a small probability to avoid trapping the algorithm in local minima

Random Neural Networks (RNN)



$$\lambda^+(i) = \sum_j q_j w_{ji}^+ + \Lambda_i$$

$$\lambda^-(i) = \sum_j q_j w_{ji}^- + \lambda_i$$

$$q_i = \frac{\lambda^+(i)}{r(i) + \lambda^-(i)} \qquad ;1 \le i \le N$$

Reinforcement Learning in RNN

- Measured performance (with respect to a particular routing goal) is used to adjust the weights of the RNN

- Example of routing goal:

  - $G = 1/D$; D = delay

Power-Aware Routing Goal

$$G_{id} = P_p(n_i, n_d)D(n_i, n_d) + [1 - P_p(n_i, n_d)](T_o + G_i)$$

$$P_p(n_i, n_d) = \prod_{j=i}^{d-1} P_n(n_{i+1})P_l(n_i, n_{i+1})$$

$$P_n(n_i) = \frac{B_i}{B_m}$$

Gid = goal at node i to destination d

Pp = path availability, To = time penalty, Bi = battery level

Pn, Pl = Probability of being available of nodes and links

Simulation

- NS-2
- 50 nodes divided into 2 populations:
  - 10 nodes (full battery charge = 2 hours operation)
  - 40 nodes (1/8 of full battery charge = 15 min)
- Area: 1500 x 500 m
- Assume random starting locations and random waypoint mobility at 2 m/s with no pause
- Traffic: 5 concurrent connections between nodes of the first population
- Smart packets sent at a ratio of 0.01

Number of nodes with no residual energy over time

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Packets Delivered to Destination

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Total DP and SP Transmitted

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Total DP and SP Received

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Summary

- CPN offers “best effort” QoS routing with smart packets both for wireline and wireless networks
- A focused information collection mechanism allows smart packets make decisions towards the desired QoS target
- Decisions can be tailored to enable energy-awareness, which in combination with delay gives balance between fast routes and an intelligent distribution of energy consumption in the network

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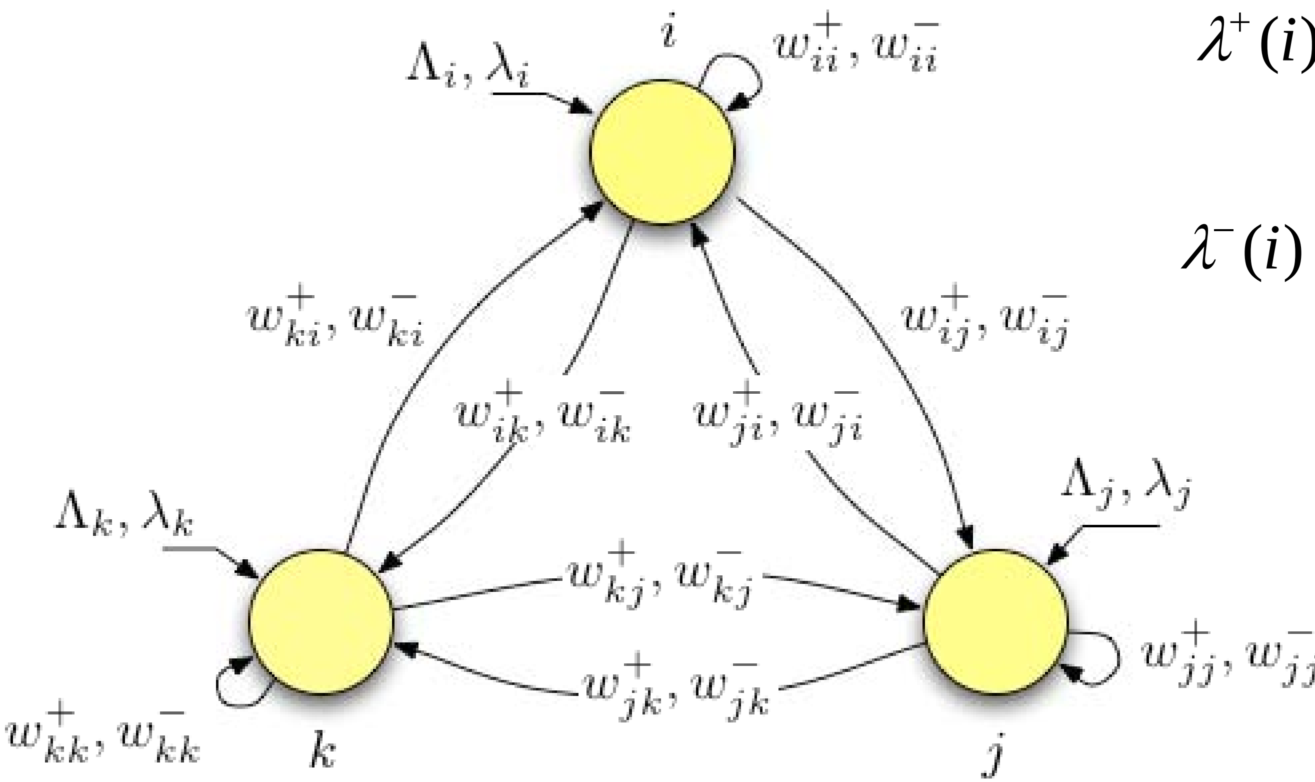

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